Introduction to

NATIONAL INSTRUMENTS

LabVIEW™

Outline

- *Definitions about Labview*
- *Main features and advantages*
- *Environment*
- *G-Language principal components*
- *Labview in a measurement scenario*

Introduction to NI LabVIEW

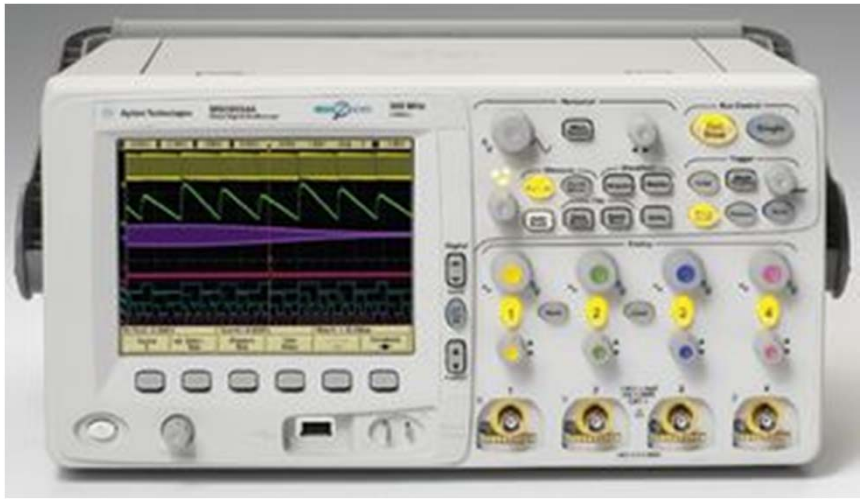
LabVIEW alias **LAB**oratory **V**irtual **I**nstruments **E**ngineering **W**orkbench
is a **programming environment** in which you create programs using a **graphical notation**
(connecting functional nodes via wires through which data flows)

It is much more than a programming language
Programs that take weeks or months to write using conventional programming languages can be completed in hours using LabVIEW because it is **specifically designed to take measurements, analyze data, and present results to the user.**

LabVIEW can create programs that run on:

- PC Windows/Mac OS X/Linux (portability across platforms)
- PDAs Microsoft pocket PC/ Microsoft Windows CE/Palm OS
- Real Time Platform NI cRIO
- Embedded systems FPGAs/DSPs/32-bit Microprocessor (Blackfin from Analog Devices)

Real Instrument (Agilent digital scope)



"Pre-defined" **User Interface**

- Buttons (boolean input)
- Knobs (numeric input)
- Display (graphical output)
- …
- …

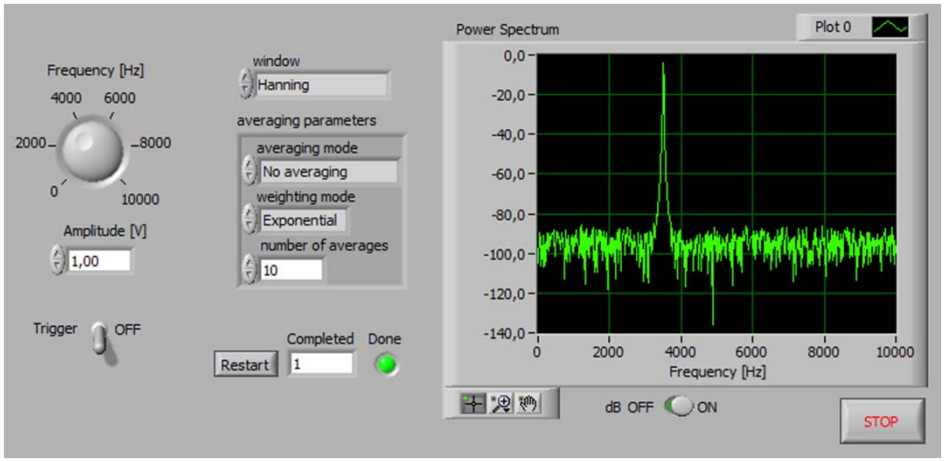
Behaviour & Features **strictly** related on hardware architecture

- ADC (resolution/sampling rate)
- Microprocessor
- Memory
- Input/Output
- …

A mid-range Digital Scope **can** (at least):

- Display Waveform (tipically up to 4)
- Perform basic measurement (time/amplitude/frequency domain)
- Connect to external equipment (GPIB/Ethernet/USB)
- Store data on external memory (usually in binary or ASCII)

Virtual Instrument



"Fully customizable" **User Interface**

- Plenty of **Controls** and **Indicators**
- Custom appeareance and behaviour
- Advanced control on user interaction
- …
- …

Behaviour is <u>software defined</u> thus fully programmable! (Block Diagram)

Features **<u>loosely</u>** related on hardware architecture → **easily upgradable**

Mid-range Laptop running LabVIEW

+

USB Data Acquisition (NI-USB 6251)

PCMCIA Data Acquisition (NI-6062E)

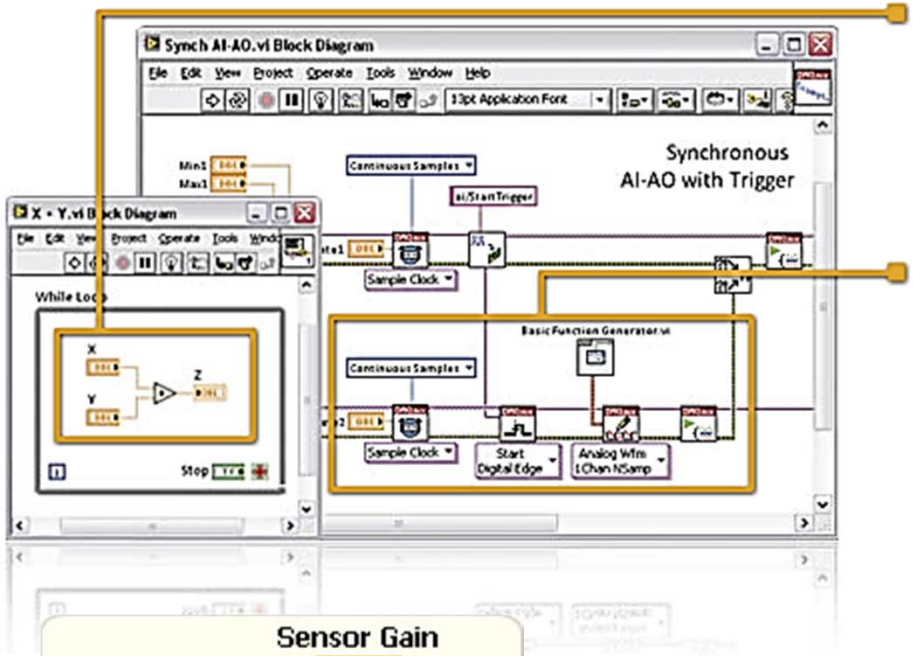
=

- Input/Output of analog/digital data
- Unlimited connectivity
- Advanced signal processing capabilities
- Efficient and flexible data storage
- Automatic report generation
- …
- …

Main features and advantages

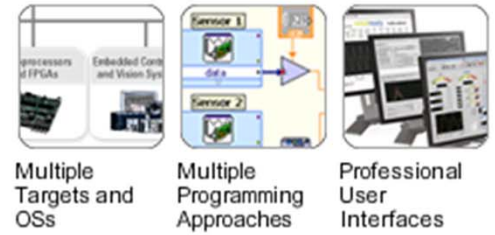
Introduction to NI LabVIEW

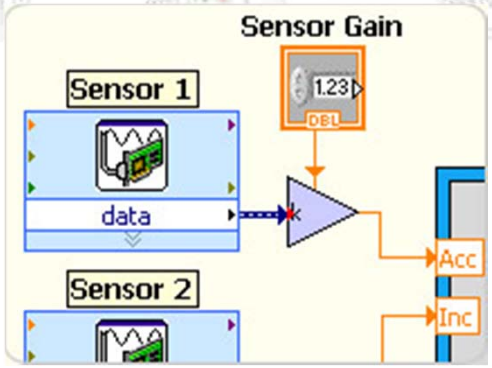
Faster Programming

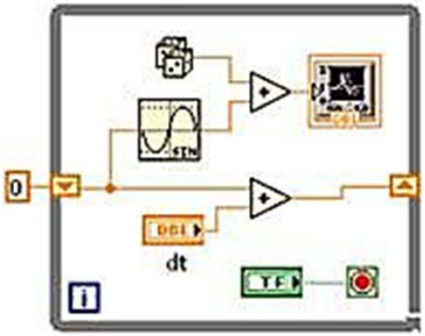


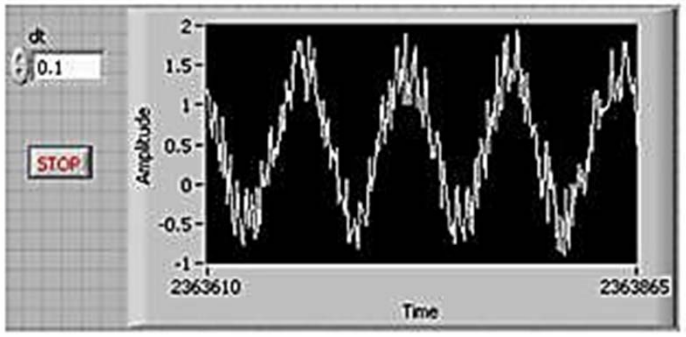
Graphical Programming
Program with drag-and-drop, graphical function blocks instead of writing lines of text

Dataflow Representation
Easily develop, maintain, and understand code with an intuitive flowchart representation





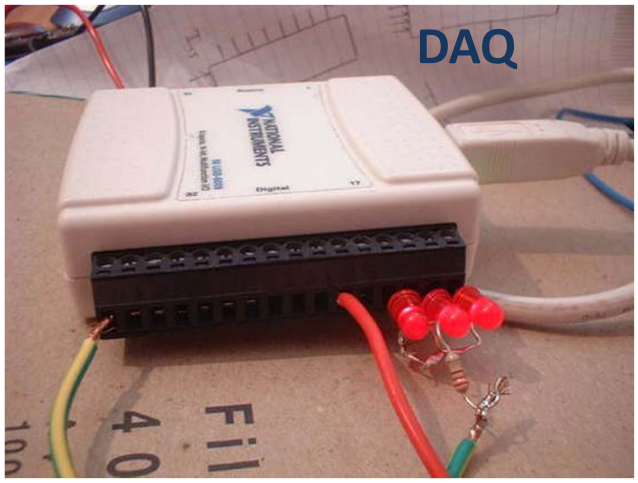




Hardware Integration

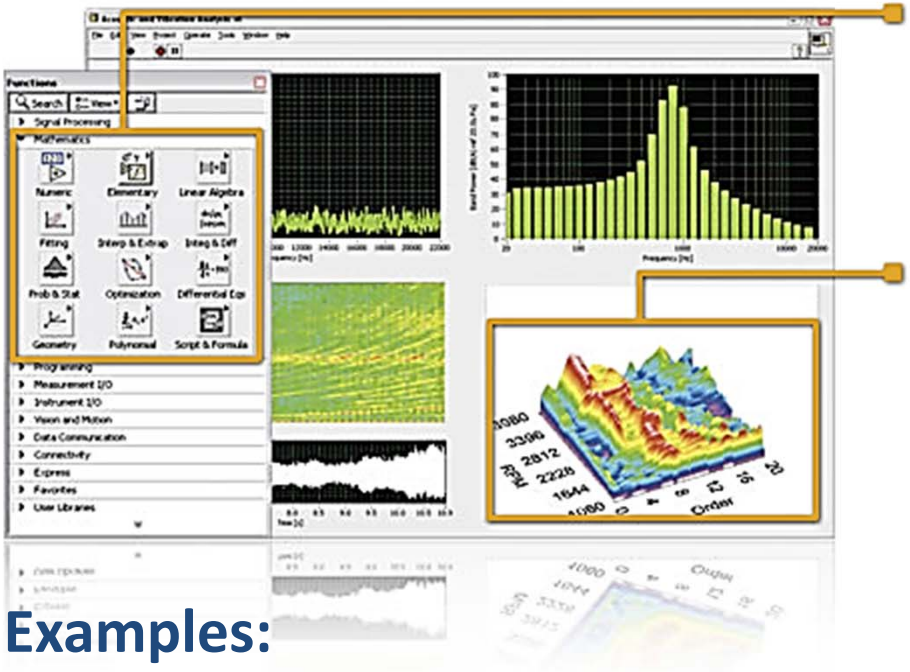
I/O and Communication
Connect to any instrument or sensor with built-in libraries and thousands of instrument drivers

Plug-and-Play Hardware
Seamlessly integrate NI plug-and-play devices for USB, PCI, PXI, Wi-Fi, Ethernet, GPIB, and more



Introduction to NI LabVIEW

Advanced Analysis



Built-In Analysis
Access thousands of engineering-specific functions such as frequency analysis, curve fitting, and more

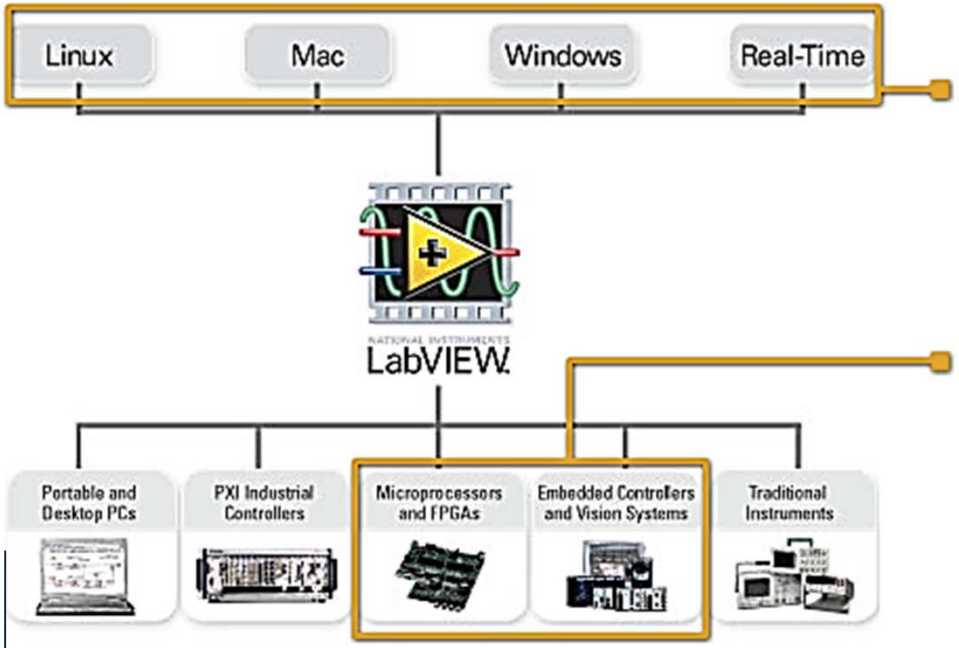
Inline Signal Processing
Interact with measurements and perform inline analysis in real time on acquired signals

Examples:

- Spectral analysis (FFT, PSD, harmonic distortion…)
- Stochastic analysis (mean, std, covariance, histogram…)
- Signal operations (convolution, deconvolution, cross-correlation…)
- Data filtering and numeric signal processing (Digital Signal Processing)
- Signal conditioning
- Data fitting and interpolation

Introduction to NI LabVIEW

Multiple Targets & OSs



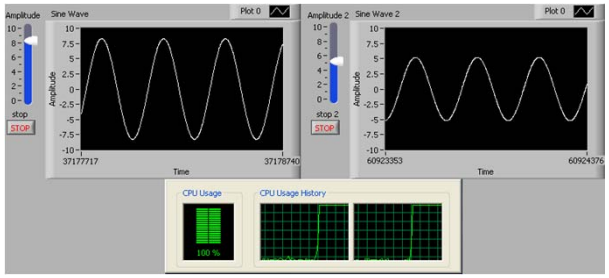
Desktop and Real-Time OSs
Develop and reuse code on Windows, Mac, Linux, and real-time OSs such as VxWorks

FPGAs and Microprocessors
Target various embedded architectures, including ARM microcontrollers and FPGAs, with the same graphical approach

Faster Programming | Hardware Integration | Advanced Analysis

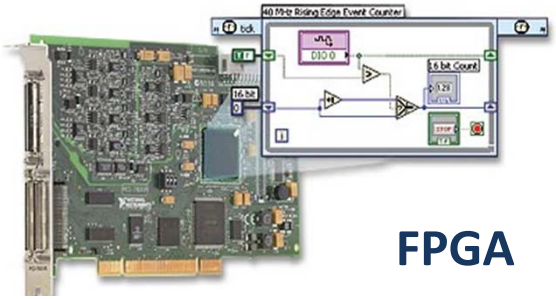
Multiple Targets and OSs | Multiple Programming Approaches | Professional User Interfaces

Portable devices



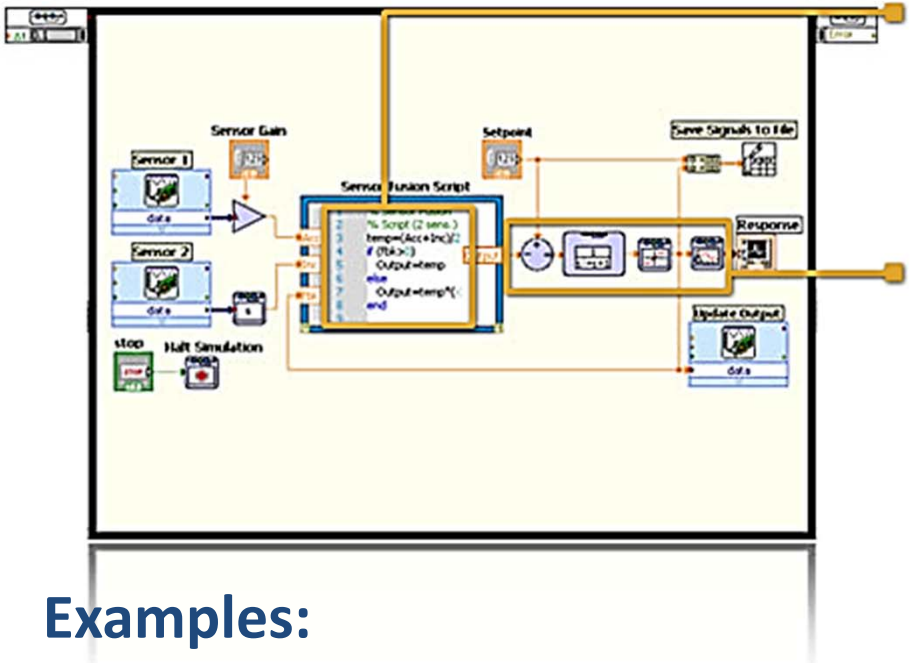
Multicore interface

Microcontrollers



FPGA

Multiple Programming Approaches

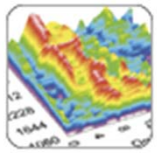


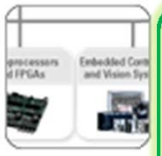
Code Reuse
Integrate text-based code and DLLs or easily incorporate native and third-party .m files

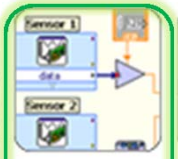
Various Design Patterns
Incorporate additional models of computation such as dynamic simulation diagrams and statecharts

Faster Programming

Hardware Integration


Advanced Analysis


Multiple Targets and OSs


Multiple Programming Approaches

Professional User Interfaces

Examples:

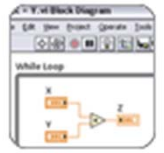
➢ Interfacing with libraries written in several programming languages (C/C++, Java, Fortran, Visual Basic and so on)
➢ Matlab .m files interface
➢ DLLs (Dinamic-Link Libraries) loading

Introduction to NI LabVIEW

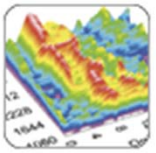
User Interfaces

Built-In Controls
Interact with data using hundreds of drag-and-drop controls, graphs, and 3D visualization tools

Custom Controls
Easily customize the position, size, and color of built-in controls or create your own in seconds


Faster Programming

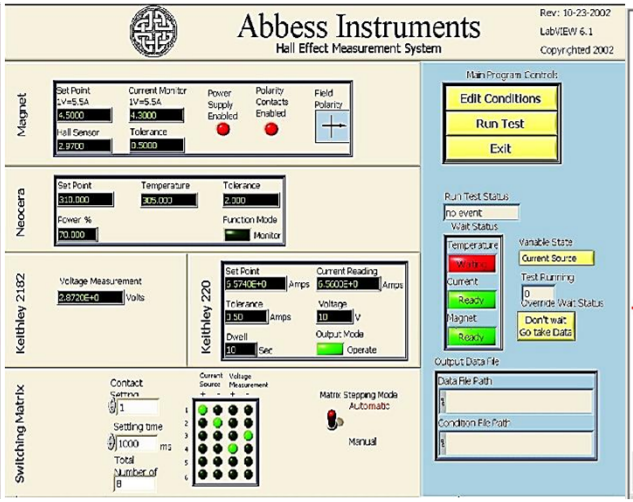
Hardware Integration

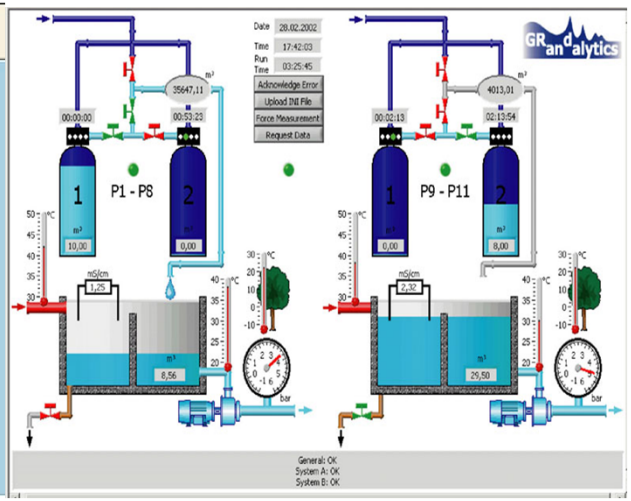

Advanced Analysis

Multiple Targets and OSs

Multiple Programming Approaches

Professional User Interfaces





Introduction to NI LabVIEW

➢ LabVIEW development system architecture

Embedded Design
- Real-Time module
- Real-Time Execution Trace Toolkit
- FPGA module
- Microprocessor SDK
- Statechart module
- Mobile module
- DSP module
- Embedded module for ADI Blackfin Processors
- Embedded Module for ARM Microcontrollers

Software Development & Deployment
- Application Builder for Windows
- VI Analyzer toolkit
- Desktop Execution Trace toolkit
- Remote panels
- Requirements Gateway
- Unit Test Framework Toolkit

Control Design & Simulation
- Control Design and Simulation module
- Fuzzy Logic Toolkit
- Simulation Interface module
- System Identification toolkit

Report Generation & Data Storage
- SignalExpress
- Report Generation Toolkit for Microsoft Office
- Database Connectivity Toolkit
- DataFinder Toolkit
- Internet Toolkit

LabVIEW core development system

Image & Signal Processing
- Vision Development
- Mathscript RT module
- Advanced Signal Processing toolkit
- Sound & Vibration Measurement suite
- Spectral Measurement suite
- Modulation toolkit
- Vision Builder for Automated Inspection
- Math Interface Toolkit

Industrial Monitoring & Control
- Datalogging and Supervisory Control module
- Wireless Sensor Network module
- Touch Panel module
- Motion Assistant
- Softmotion module

The NI LabVIEW product family consists of the LabVIEW development environment and **more than 25 add-on software tools** that extend LabVIEW graphical programming for **specific applications.**

Environment

Introduction to NI LabVIEW

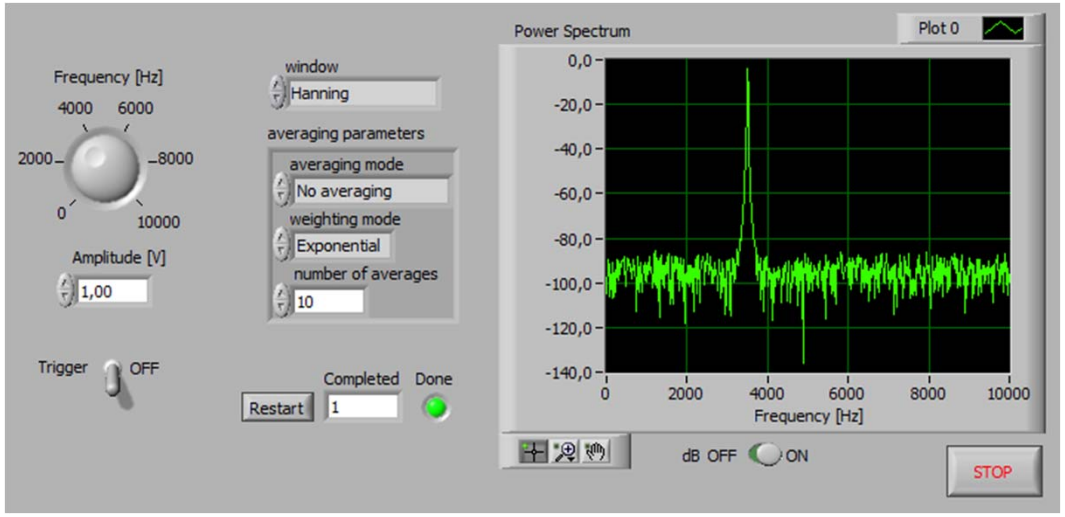
➢ Introduction to Virtual Instruments: Front Panel

*LabVIEW programs are called virtual instruments (VI) because **their appearance and operation imitate physical instruments**, such as oscilloscopes and multimeters. Every VI uses functions that manipulate input from the user interface or other sources and display that infromation or move to other file or other computers.*

LabVIEW User Manual

A VI contains the following three components:

- **Front panel –** Serves as the user interface
- **Block diagram –** Contains the graphical source code (G language) that defines the functionality of the VI
- **Icon and connector panel –** Identifies the VI so that you can use the VI in another VI. A VI within another VI is called subVI. A subVI corresponds to a subroutine in text-based programming languages.



You build the front panel with **controls and indicators**, which are the interactive input and output terminals of the VI, respectively. Controls are knobs, push buttons, dials, and other input devices. Indicators are graphs, LEDs, and other displays. **Controls simulate instruments input devices** and supply data to the block diagram of the VI. **Indicators simulate instrument output devices** and display data the block diagram acquires or generates.

Introduction to NI LabVIEW

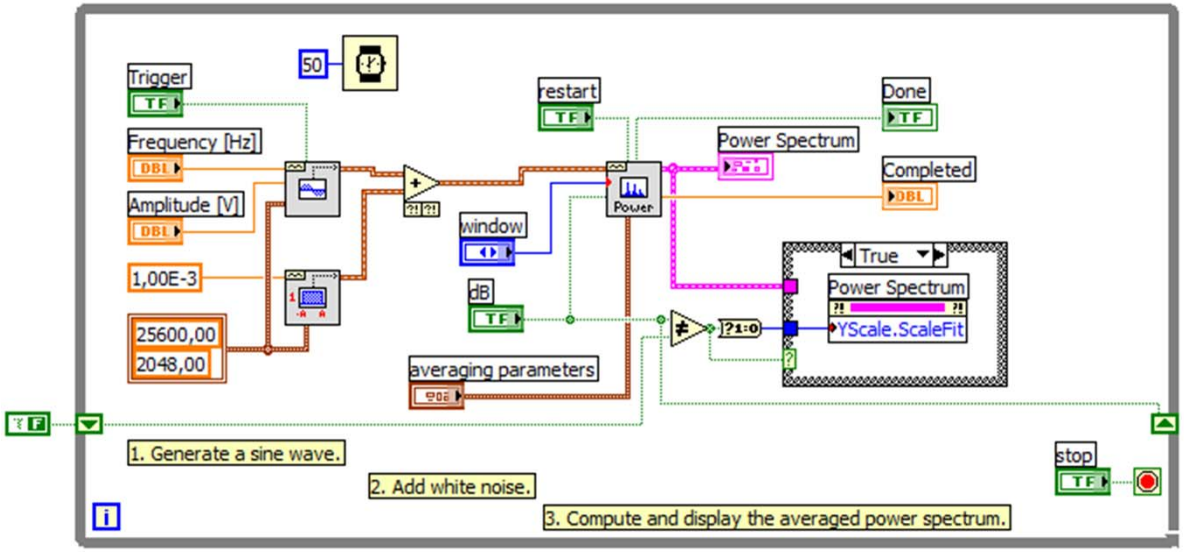
➢ Introduction to Virtual Instruments: Block Diagram

*LabVIEW programs are called virtual instruments (VI) because **their appearance and operation imitate physical instruments**, such as oscilloscopes and multimeters. Every VI uses functions that manipulate input from the user interface or other sources and display that information or move to other file or other computers.*

LabVIEW User Manual

A VI contains the following three components:

- **Front panel –** Serves as the user interface
- **Block diagram –** Contains the graphical source code (G language) that defines the functionality of the VI
- **Icon and connector panel –** Identifies the VI so that you can use the VI in another VI. A VI within another VI is called subVI. A subVI corresponds to a subroutine in text-based programming languages.



After you build the front panel, you add code using graphical representations of functions to control the front panel objects. The block diagram contains this **graphical source code**

Introduction to NI LabVIEW

➢ Introduction to Virtual Instruments: Icon & Connection Panel

*LabVIEW programs are called virtual instruments (VI) because **their appearance and operation imitate physical instruments**, such as oscilloscopes and multimeters. Every VI uses functions that manipulate input from the user interface or other sources and display that infromation or move to other file or other computers.*

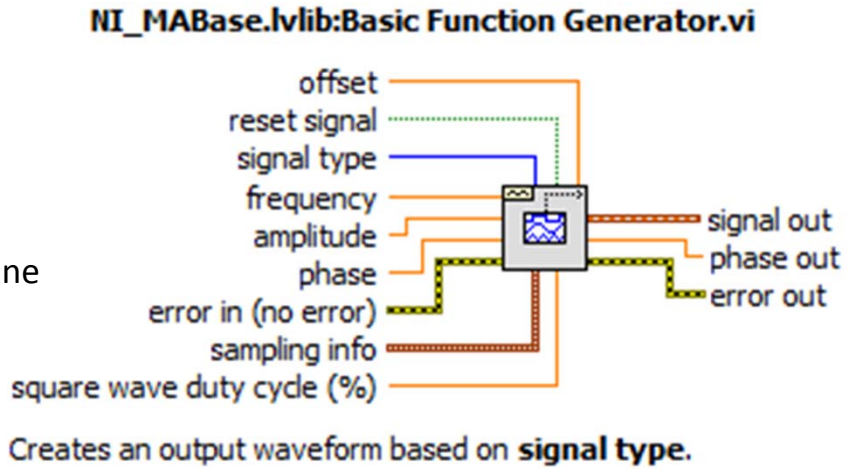
LabVIEW User Manual

A VI contains the following three components:

- **Front panel –** Serves as the user interface
- **Block diagram –** Contains the graphical source code (G language) that defines the functionality of the VI
- **Icon and connection pane –** Identifies the VI so that you can use the I in another VI. A VI within another VI is called subVI. A subVI corresponds to a subroutine in text-based programming languages.

Icon

Connection pane



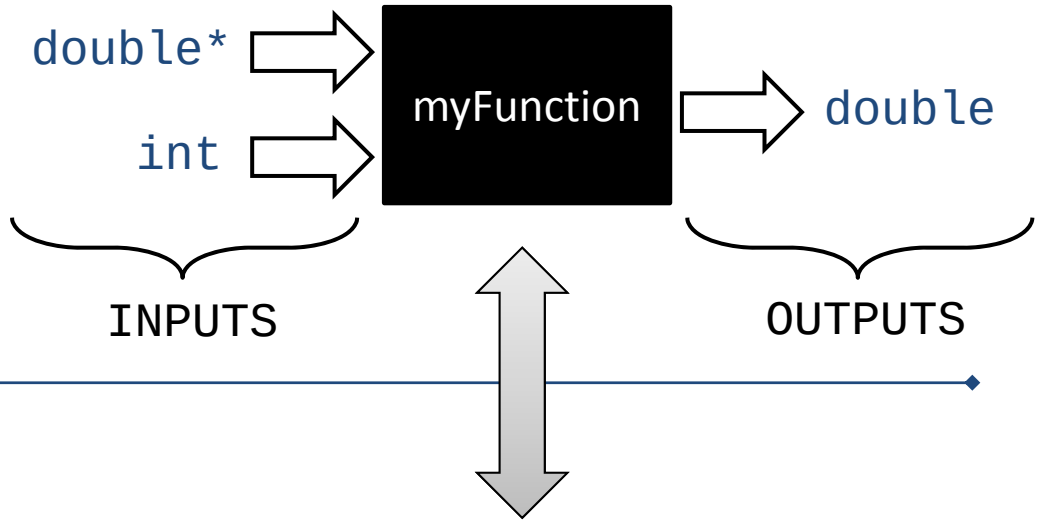
The Icon identifies the VI so you can use it in another VI

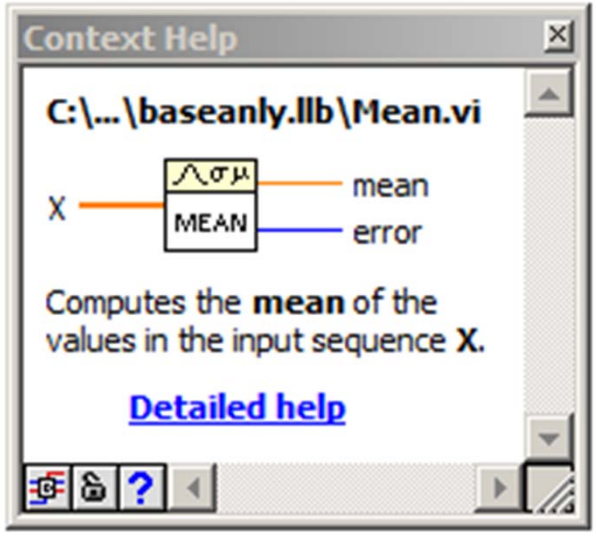
The connector pane is a set of terminals that corresponds to the controls and indicators of that VI, *similar to the parameter list of a function call in text-based programming languages*. The connector pane defines the inputs and outputs you can wire to the VI

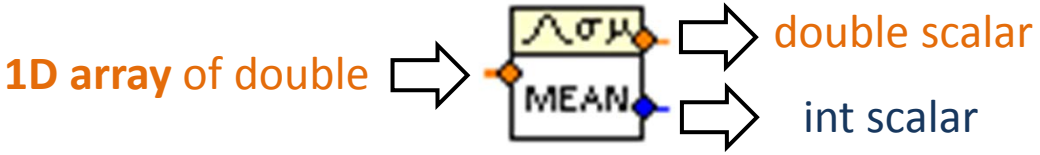
G-Language principal components

```
double myFunction (double* a, int size)
{
  double result = 0;
  int tempSize = size;

  while (tempSize-->0)
    result += *a++;

  return result/size;
}
```

Black-box approach; we only need the prototype







The connection pane of LabVIEW nodes plays the same role of the function prototype in a traditional text-based programming language

Introduction to NI LabVIEW

➢ LabVIEW G-Language: Data Types

In LabVIEW there are 32 different data types. The color and symbol of each terminal indicate the data type of the corresponding control or indicator. In the following table the 9 most common are reported.

Control	Indicator	Description
		Float. Double-precision, floating-point numeric
		Integer. 32-bit signed integer numeric
		Boolean. Stores Boolean (TRUE/FALSE) values.
		String. Provides a platform-independent format for information and data, which you can use to create simple text messages, pass and store numeric data, and so on.
		Array. Encloses the data type of its elements in square brackets and takes the color of that data type. As you add dimensions to the array, the brackets become thicker.
		Cluster. Encloses several data types. Cluster data types appear brown if all elements in the cluster are numeric or pink if all elements of the cluster are of different types. Error code clusters appear dark yellow, while LabVIEW class clusters are crimson by default or teal green for Report Generation VIs.
		Dynamic data. (Express VIs) Includes data associated with a signal and the attributes that provide information about the signal, such as the name of the signal or the date and time the data was acquired.
		Waveform. Carries the data, start time, and t of a waveform.
		I/O. Passes resources you configure to I/O VIs to communicate with an instrument or a measurement device.

Nodes are objects on the block diagram that have inputs and/or outputs and perform operations when a VI runs.

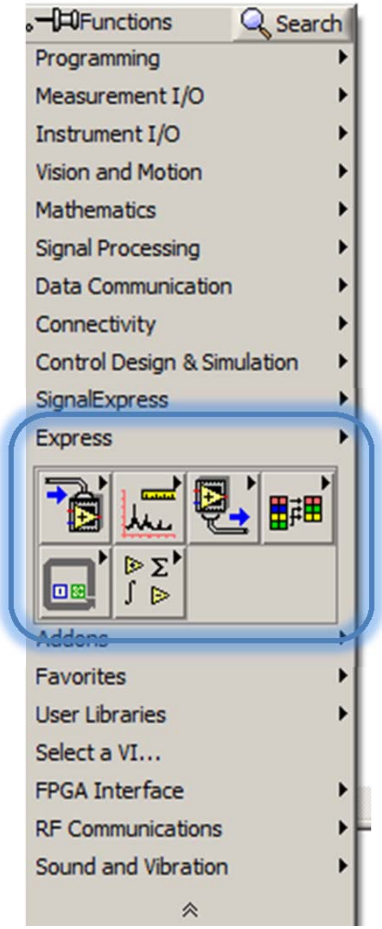
They are analogous to statements, operators, functions, and subroutines in text-based programming languages. LabVIEW includes the following types of nodes:

- **Functions**—Built-in execution elements, comparable to an operator, function, or statement.
- **SubVIs**—VIs used on the block diagram of another VI, comparable to subroutines.
- **Express VIs**—SubVIs designed to aid in common measurement tasks. You configure an Express VI using a configuration dialog box.
- **Structures**—Execution control elements, such as For Loops, While Loops, Case structures, Flat and Stacked Sequence structures, Timed structures, and Event structures.
- **Formula and Expression Nodes**—Formula Nodes are resizable structures for entering equations directly into a block diagram. Expression Nodes are structures for calculating expressions that contain a single variable.

Introduction to NI LabVIEW

➢ LabVIEW G-Language: Express VIs

An **Express VI** is a VI whose settings you can configure interactively through a dialog box. Express VIs appear on the block diagram as expandable nodes with icons surrounded by a blue field.

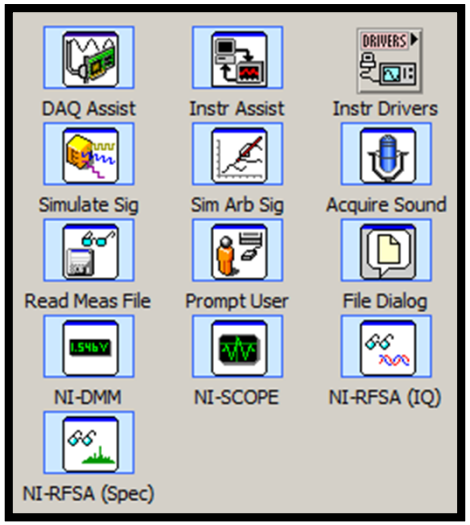


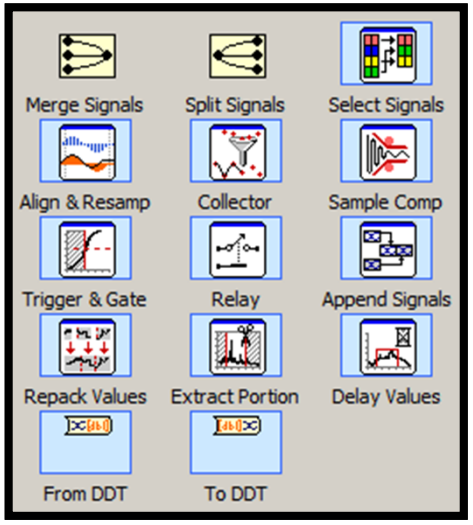
You can configure an Express VI by setting options in the **configuration dialog box** that appears when you place the Express VI on the block diagram.

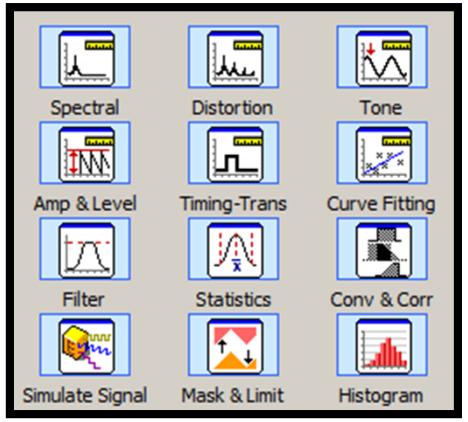
The primary benefit of Express VIs is their **interactive configurability**. Express VIs are useful when you want to give users a VI or library of VIs for building their own applications easily *with minimal programming expertise.*

Express VIs **do not provide run-time interactive configuration for VIs**. If you need run-time reconfiguration, build an application with a user interface that contains features similar to a configuration dialog box. Express VIs are designed for ease of use.

If you need an application to run with strict memory restrictions or high execution speeds, use standard VIs.

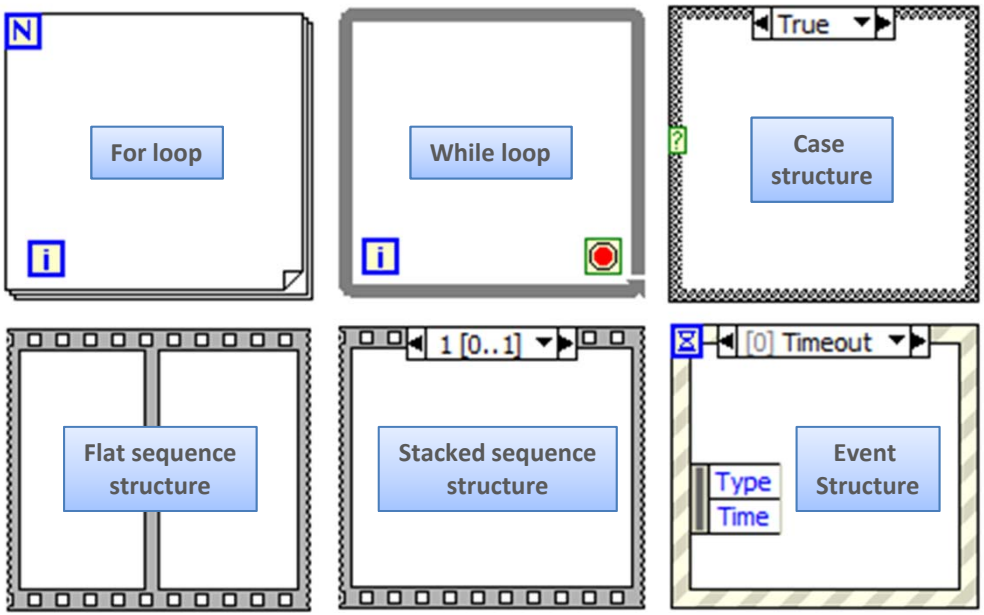






Structures are graphical representations of the loops and case statements of text-based programming languages. Use structures on the block diagram to repeat blocks of code and **to execute code conditionally or in a specific order**. Like other nodes, structures have terminals that connect them to other block diagram nodes, execute automatically when input data is available, **and supply data to output wires when execution completes**.

Each structure has a distinctive, resizable **border** to enclose the section of the block diagram that executes according to the rules of the structure. The section of the block diagram inside the structure border is called a subdiagram. The terminals that feed data into and out of structures are called **tunnels**. A tunnel is a connection point on a structure border.



For Loop—Executes a subdiagram a set number of times or, if you add a conditional terminal, until a Boolean condition or an error occurs.

While Loop—Executes a subdiagram until a Boolean condition or an error occurs.

Case structure—Contains multiple subdiagrams, only one of which executes depending on the input value passed to the structure.

Sequence structure—Contains one or more subdiagrams that execute in sequential order.

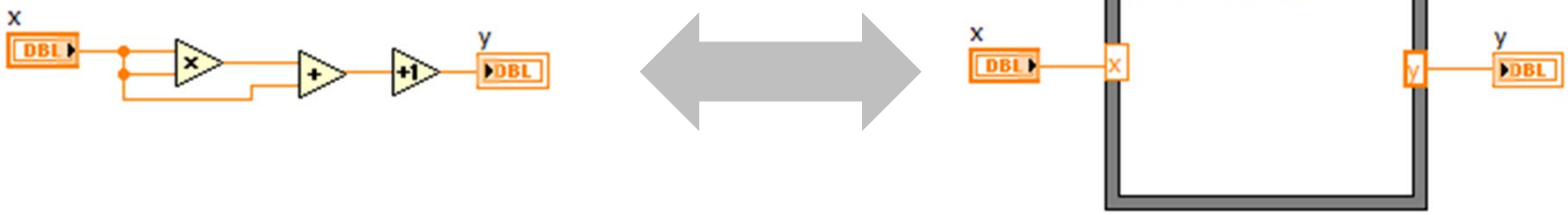
Event structure—Contains one or more subdiagrams that execute when events are generated by user interaction.

Timed structures—Execute one or more subdiagrams with time bounds and delays.

Conditional Disable structure—Contains one or more subdiagrams, exactly one of which compiles and executes at run-time.

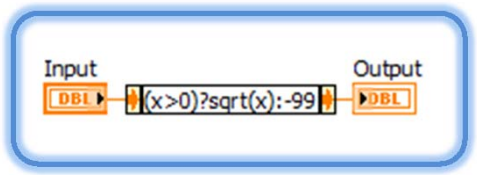
Diagram Disable structure—Contains one or more subdiagrams, exactly one of which compiles and executes at run-time.

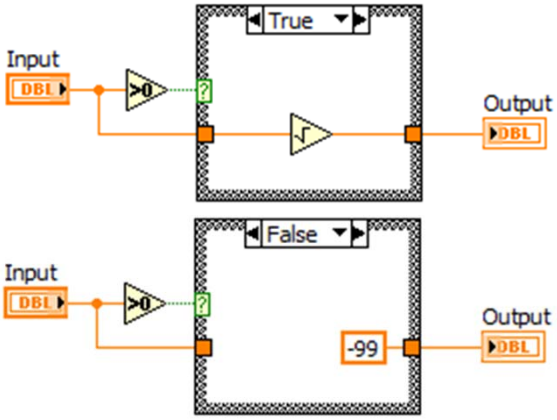
The **Formula Node** is a resizable box that you use to enter algebraic formulas directly into the block diagram. You will find this feature extremely useful when you have a long formula to solve. For example, consider the fairly simple equation, $y = x^2 + x + 1$. Even for this simple formula, if you implement this equation using regular LabVIEW arithmetic functions, the block diagram is a little bit harder to follow than the text equations

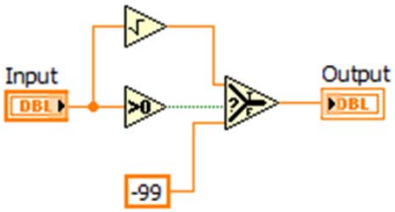


The **Expression Node** is basically just a simplified **Formula Node** having just one unnamed input and one unnamed output. You do not have to name the input or output terminals and to put semicolons at the end.

The same operators and syntax of the Formula Node apply to the Expression Node.







A LabVIEW **array** is a collection of data elements that are **all the same type**, just like in traditional programming languages.

An array data element can have any type except another array, a chart, or a graph.

Array elements are accessed by their indices; each element's index is in the range **0 to N-1**, where **N** is the total number of elements in the array. Notice that, along each dimension, **the first element has index 0**, the second element has index 1, and so on.

- Data type
- Number of dimensions, **D**
- Total number of elements, **N**

We access the array elements by **D**x**N** indices, **I**

1.23
0.67
-34

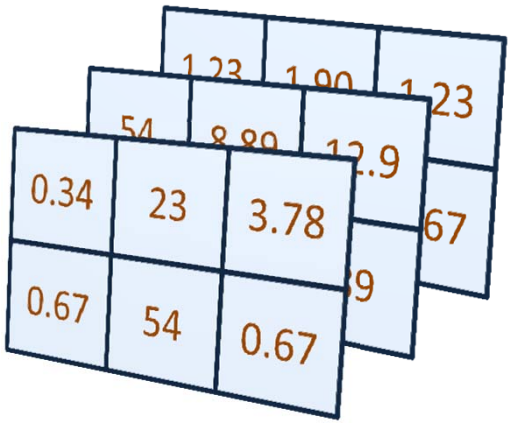
3x1
D = 1
N = 3

I: {i}
i=0:1

1.23	1.90
0.67	12
-34	0.25

3x2
D = 2
N = 6

I: {i,j}
i=0:2, j=0:1



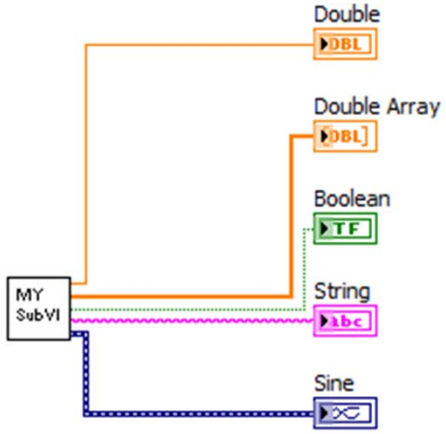
2x3x3
D = 3
N = 18

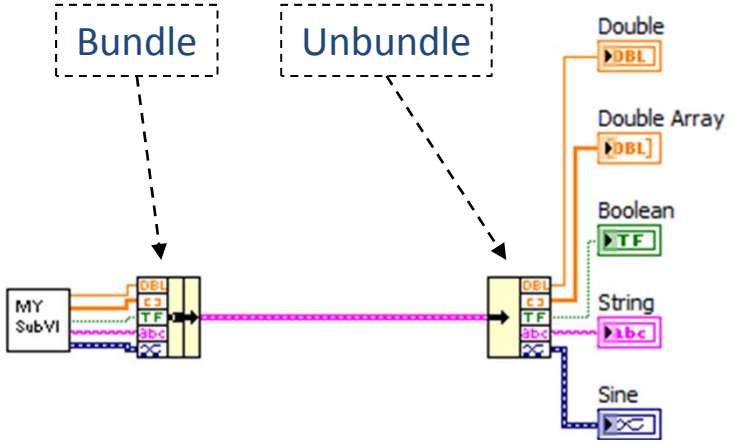
I: {i,j,k}
i=0:1, j=0:2, k=0:2

Like an array, a cluster is a data structure that groups data. However, unlike an array, a cluster can group data of different types (i.e., numeric, Boolean, etc.); it is analogous to a struct in C or the data members of a class in C++ or Java.

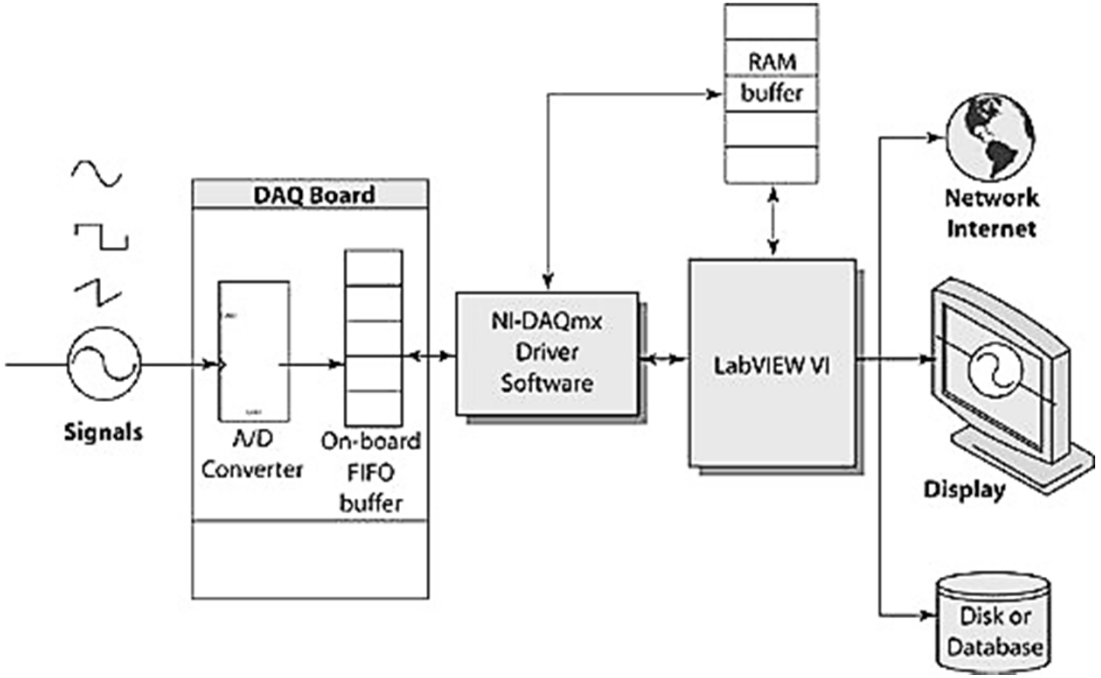
Because a cluster has only one "wire" in the block diagram **clusters reduce wire clutter and the number of connector terminals that subVIs need**

- **You can access cluster elements by unbundling them all at once or by indexing one at a time**, depending on the function you choose; each method has its place
- Unlike arrays, which can change size dynamically, **clusters have a fixed size**, or a fixed number of wires in them.
- **You can connect cluster terminals with a wire only if they have exactly the same type**; in other words, both clusters must have the same number of elements, and corresponding elements must match in both data type and order.





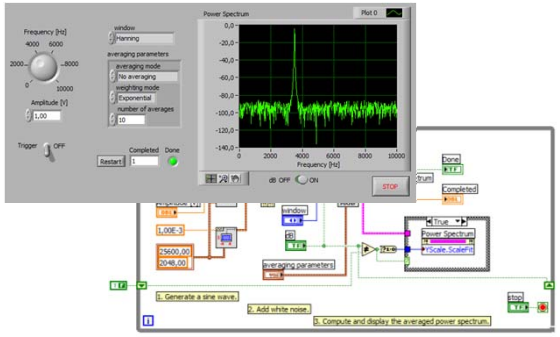
Labview in a measurement scenario



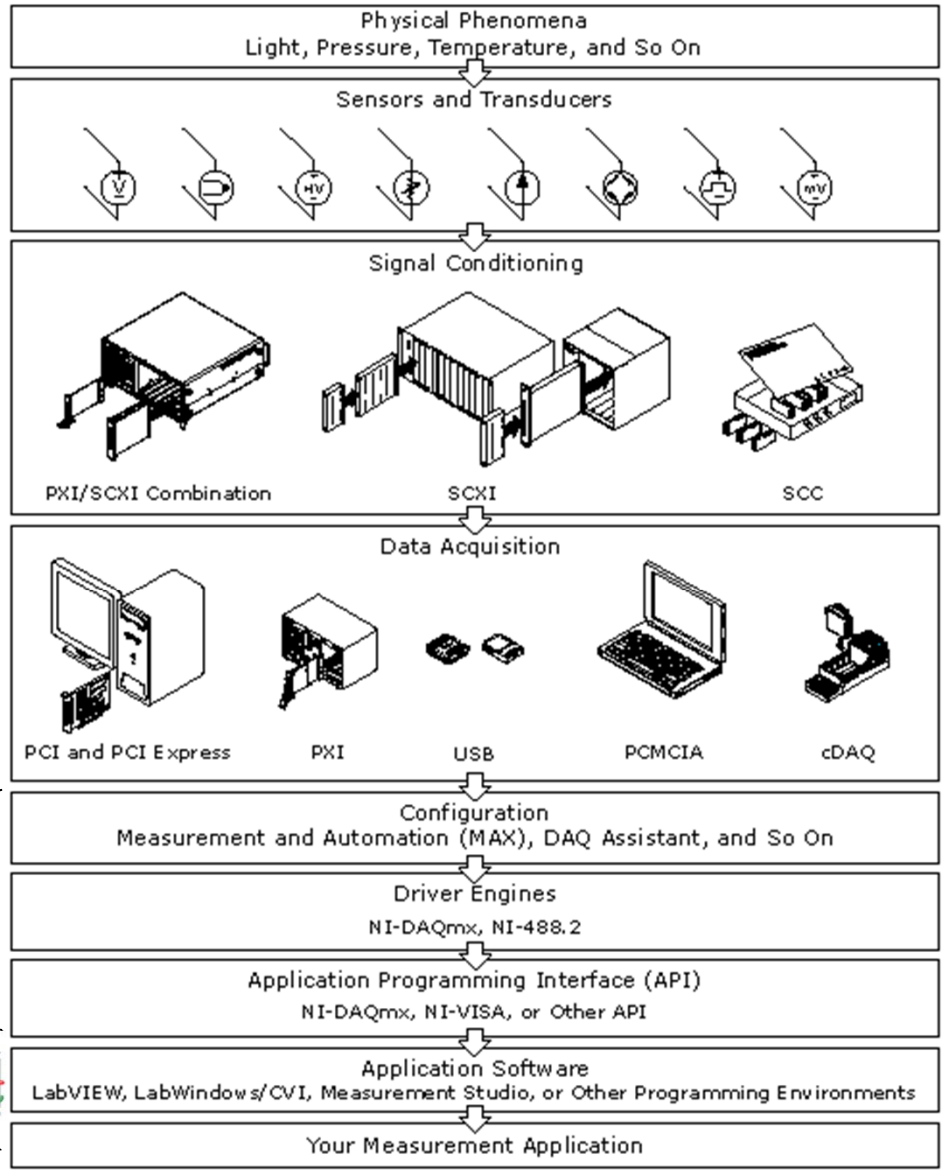
Introduction to NI LabVIEW

The typical measurement scenario

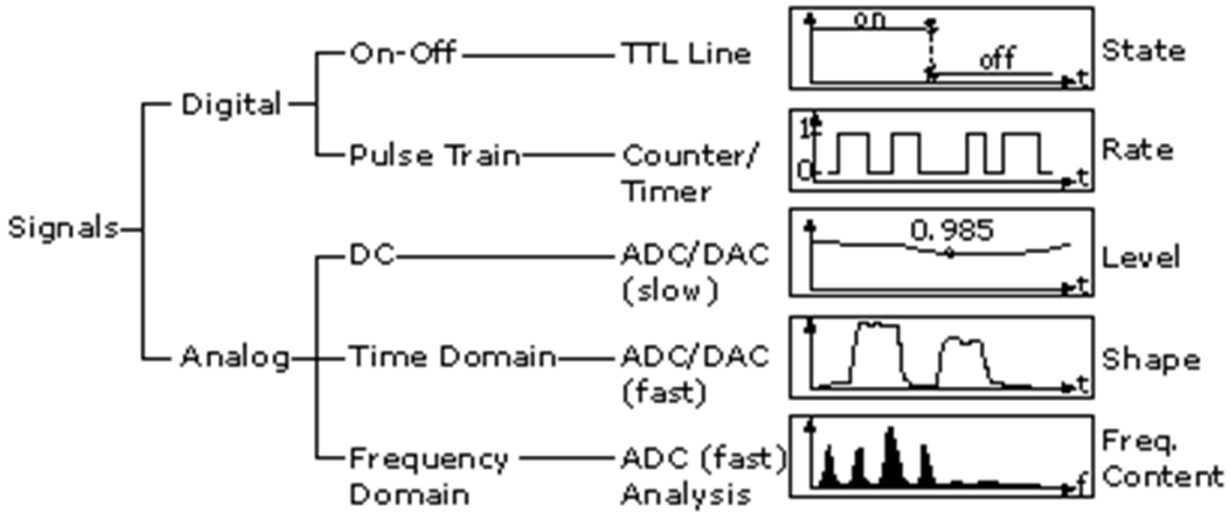
- **Sensors and transducers** detect physical phenomena.
- **Signal conditioning** components condition physical phenomena so that the measurement device can receive data.
- The computer receives the data through the **measurement device**.
- **Software** controls the measurement system, telling the measurement device when and from which channels to acquire or generate data.
- Software also takes the raw data, analyzes it, and **presents it in a form you can understand**, such as a graph, chart, or file for a report.



MAX+NI-DAQmx



Strictly speaking, all signals are analog time-varying signals. However, to discuss signal measurement methods, you should classify a given signal as one of five signal types.

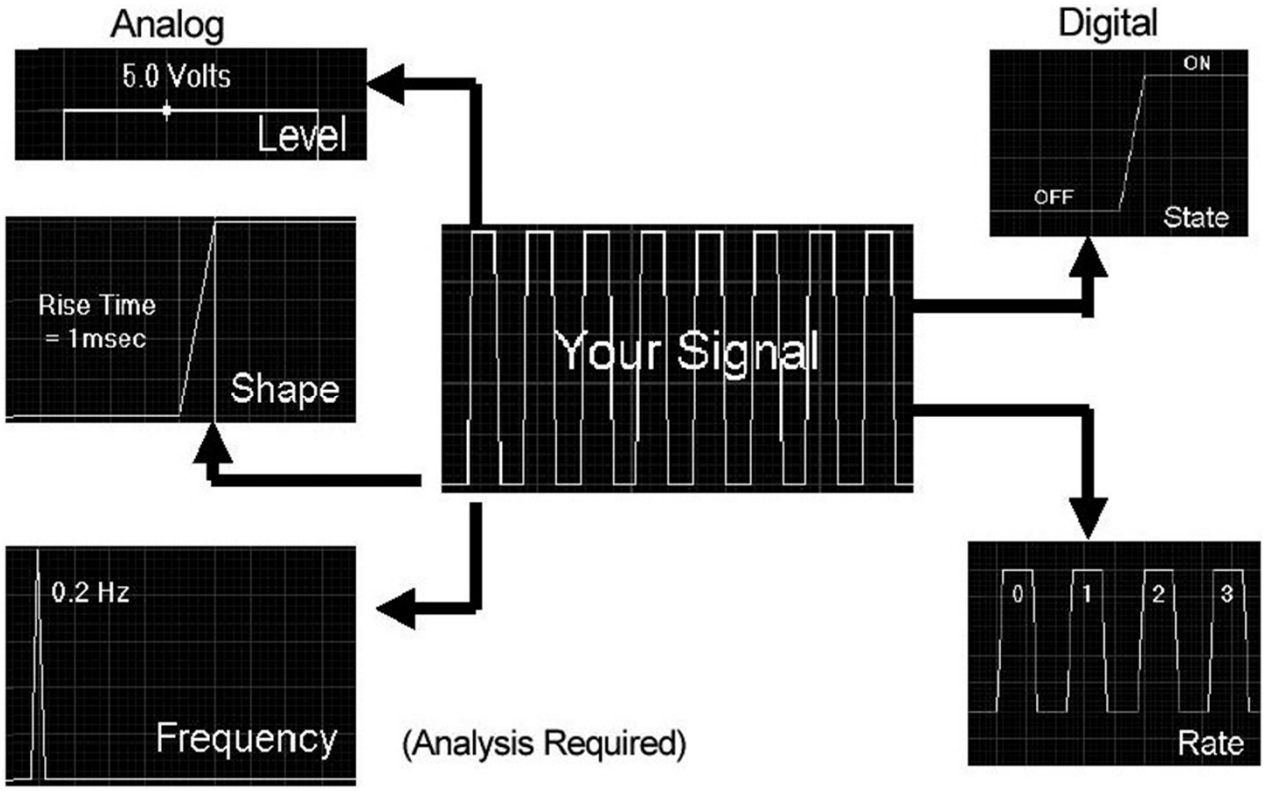


A signal is classified as **analog** or **digital** by the way it conveys information.

- A digital (or binary) signal has only two possible discrete levels—high level (on) or low level (off).
- An analog signal, on the other hand, contains information in the continuous variation of the signal with respect to time.

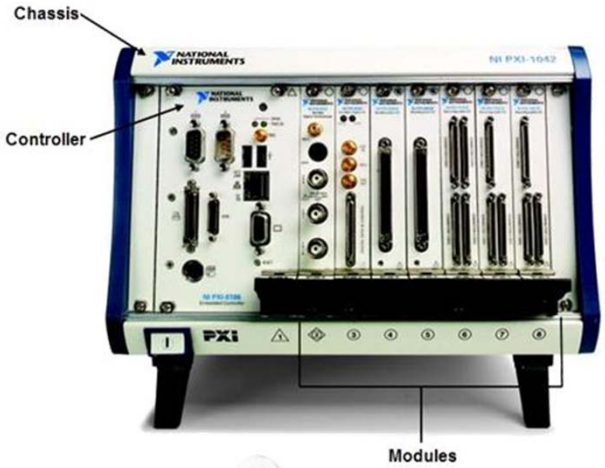
Strictly speaking, all signals are analog time-varying signals. However, to discuss signal measurement methods, you should classify a given signal as one of five signal types.

One Signal, Five Measurement Perspectives



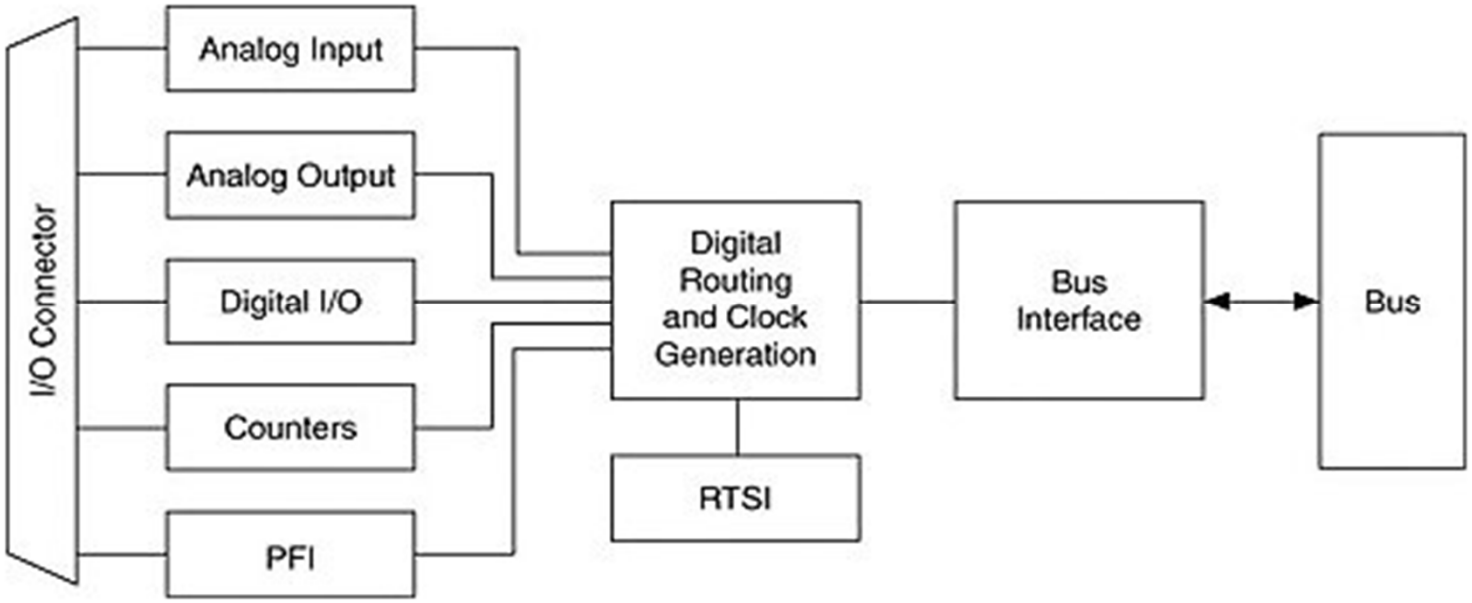
Bus Considerations

- PCI & PCIexpress (best throughput and latency performances)
- USB (portability, plug&play)
- WI/FI – Ethernet (wireless or wired remote measurement)
- PXI – PXIexpress (modular, high-bandwidth open-PC based platform)



Introduction to NI LabVIEW

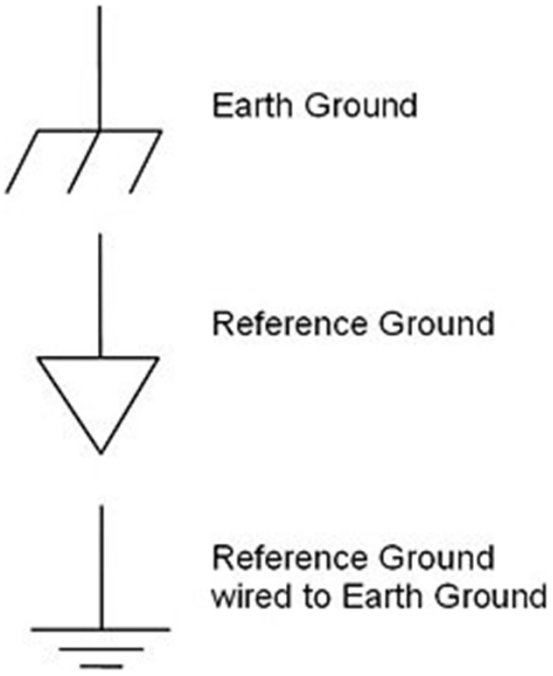
- 16- or 18-bit, up to 1.25 MS/s, up to 80 analog inputs
- Up to 4 analog outputs at 16 bits, 2.8 MS/s (2 µs full-scale settling)
- Up to 48 TTL/CMOS digital I/O lines (up to 32 hardware-timed at 10 MHz)
- Two 32-bit, 80 MHz counter/timers
- NI-DAQmx driver software and NI LabVIEW SignalExpress LE interactive data-logging software
- NI-MCal calibration technology for improved measurement accuracy by up to 5X



Virtual channels define real-world measurements consisting of one or more DAQ channels (terminals on your DAQ device) along with other channel-specific information: range, terminal configuration, and custom scaling that is used to format the data.

An **NI-DAQmx Task** is a collection of one or more virtual channels along with timing, triggering, and other properties. Conceptually, a task represents a measurement or generation you want to perform. For example, a task allows you to specify whether you want to measure 1 sample, measure N samples, or measure continuously (using a buffer to store data). A task also allows you to specify the sample rate, the timing clock source, and the task triggers. Once you have defined a task, you can simply start the task, read the task data, and stop the task from within LabVIEW.

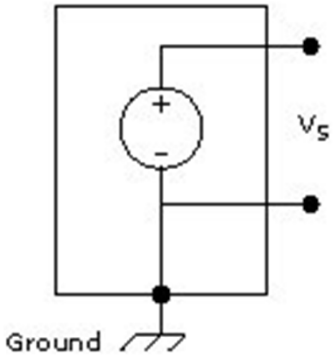
Voltage is not absolute; it always requires a reference to be meaningful. Voltage is always the measure of a potential difference between two bodies. One of these bodies is usually picked to be the reference and is assigned "0 V." So to talk about a 3.47 V signal really means nothing unless we know with respect to what reference.



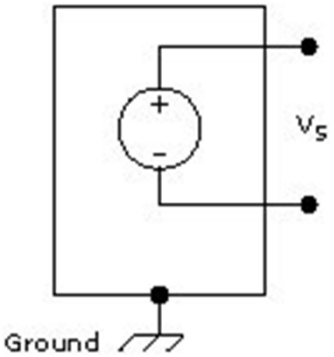
Earth ground refers to the potential of the earth below your feet. Most electrical outlets have a prong that connects to the earth ground, which is also usually wired into the building electrical system for safety. Many instruments also are "grounded" to this earth ground, so often you'll hear the term system ground. The main reason for this type of grounding is safety, and not because it is used as a reference potential. In fact, you can bet that no two sources that are connected to the earth ground are at the same reference level; the difference between them could easily be up to 10 volts.

Reference ground, sometimes called a return path or signal common, is usually the reference potential of interest. The common ground may or may not be wired to earth ground. The point is that many instruments, devices, and signal sources provide a reference (the negative terminal, common terminal, etc.) that gives meaning to the voltages we are measuring.

The DAQ devices in your computer are also expecting to measure voltage with respect to some reference. What reference should the DAQ device use? You have your choice, which will depend on the kind of signal source you're connecting. Signals can be classified into two broad categories, as follows:



A **grounded source** is one in which the voltage signals are referenced to a system ground, such as earth or building ground. Because they use the system ground, they share a common ground with the DAQ device. The most common examples of grounded sources are devices that plug into the building ground through wall outlets, such as signal generators and power supplies.

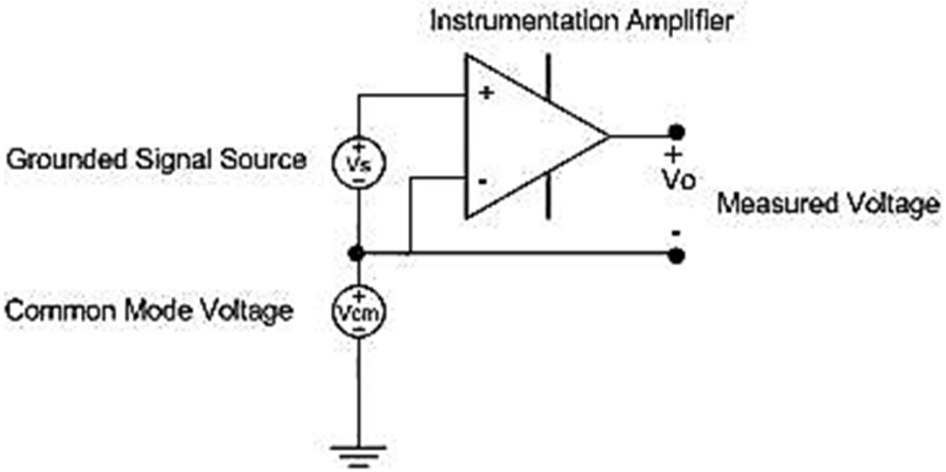


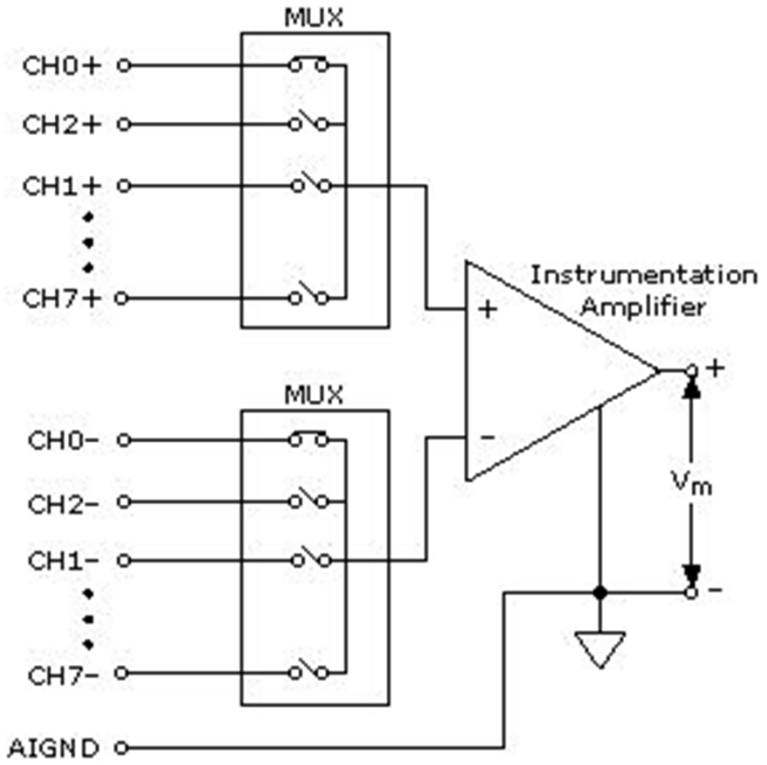
A **floating source** is a source in which the voltage signal is not referenced to any common ground, such as earth or building ground. Some common examples of floating signal sources are batteries, thermocouples, transformers, and isolation amplifiers. Notice that neither terminal of the source is connected to the electrical outlet ground. Thus, each terminal is independent of the system ground.

To measure your signal, you can almost always configure your DAQ device to make measurements that fall into one of these three categories: *Differential, Referenced Single Ended, Nonreferenced Single-Ended*

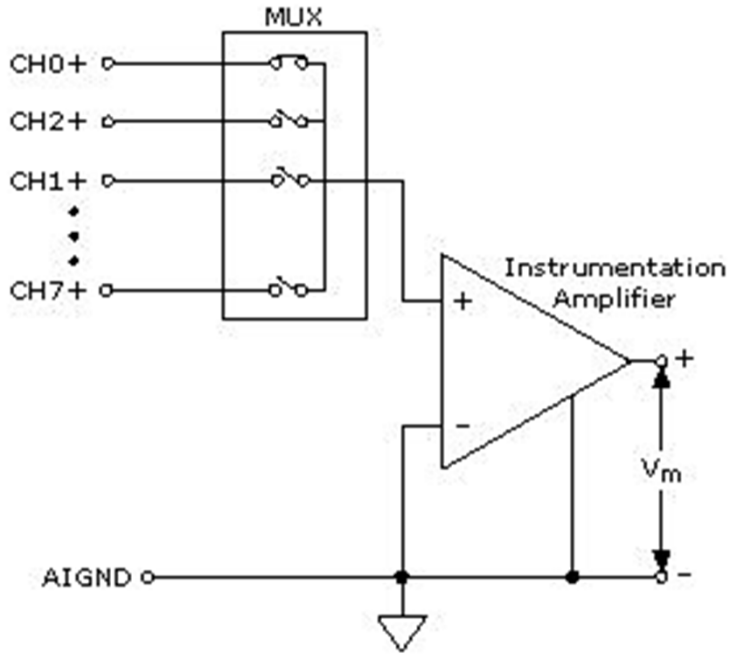
In a differential measurement system, neither input is connected to a fixed reference such as earth or building ground. Most DAQ devices with instrumentation amplifier can be configured as differential measurement systems. The figure above depicts the eight-channel differential measurement system used in the E-series DAQ devices. Analog multiplexers increase the number of measurement channels while still using a single instrumentation amplifier. For this device, the pin labeled AIGND (the analog input ground) is the measurement system ground.

An ideal differential measurement system reads only the potential difference between its two terminals the (+) and (-). Any voltage present at the instrumentation amplifier inputs with respect to the amplifier ground is referred to as a common-mode voltage. An ideal differential measurement system completely rejects (does not measure) common-mode voltage.

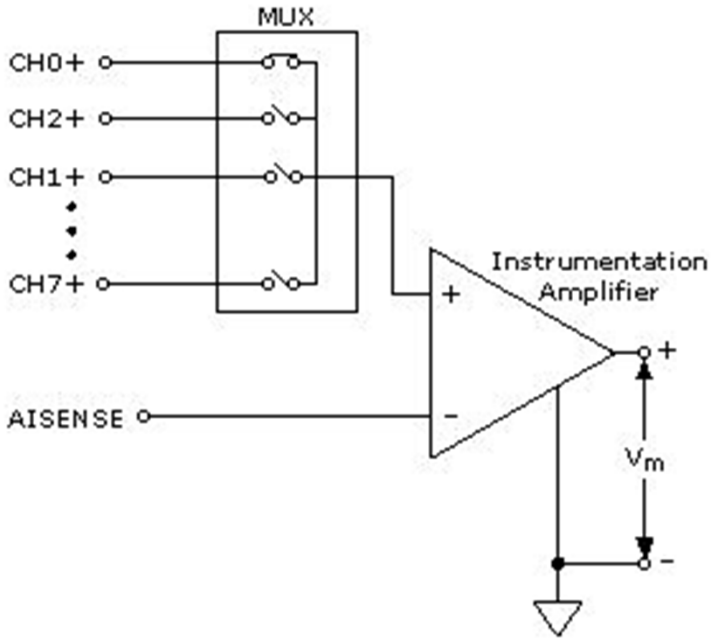




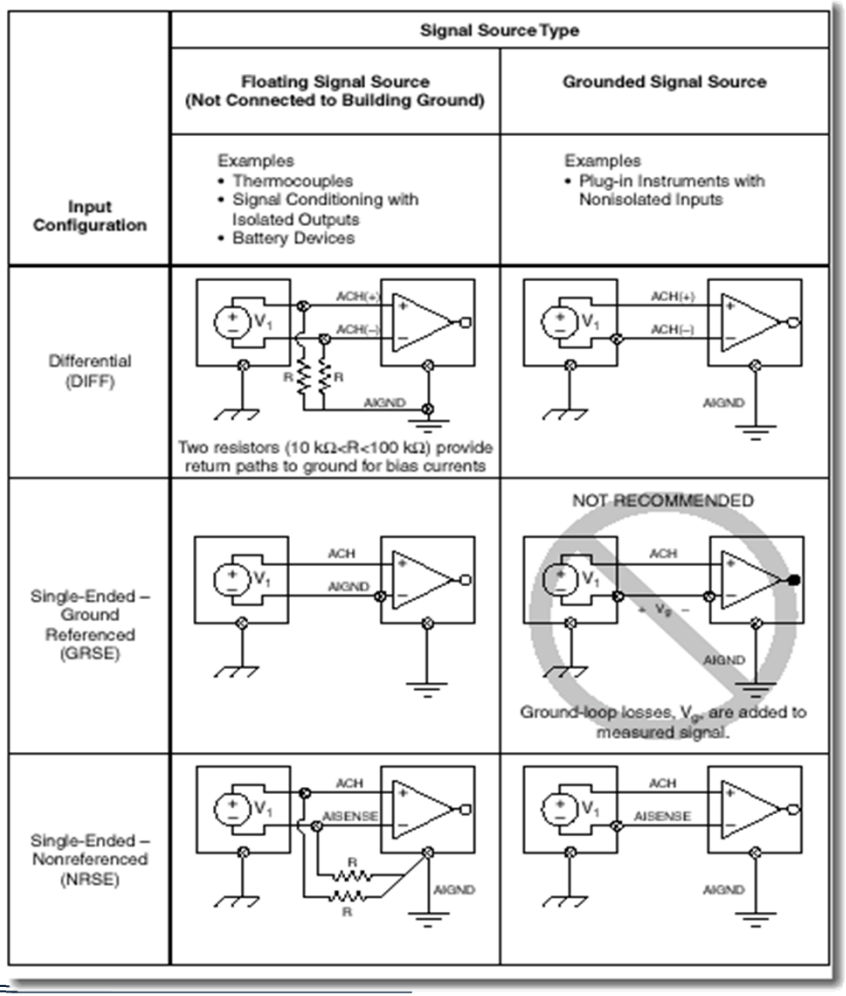
A referenced single-ended (RSE) measurement system, also called a grounded measurement system, is similar to a grounded signal source, in that the measurement is made with respect to earth ground. The figure above depicts a 16-channel RSE measurement system.



In an nonreferenced single-ended (NRSE) measurement system, all measurements are made with respect to a common reference ground, but the voltage at this reference can vary with respect to the measurement system ground. *AISENSE is the common reference for taking measurements and AIGND is the system ground.*



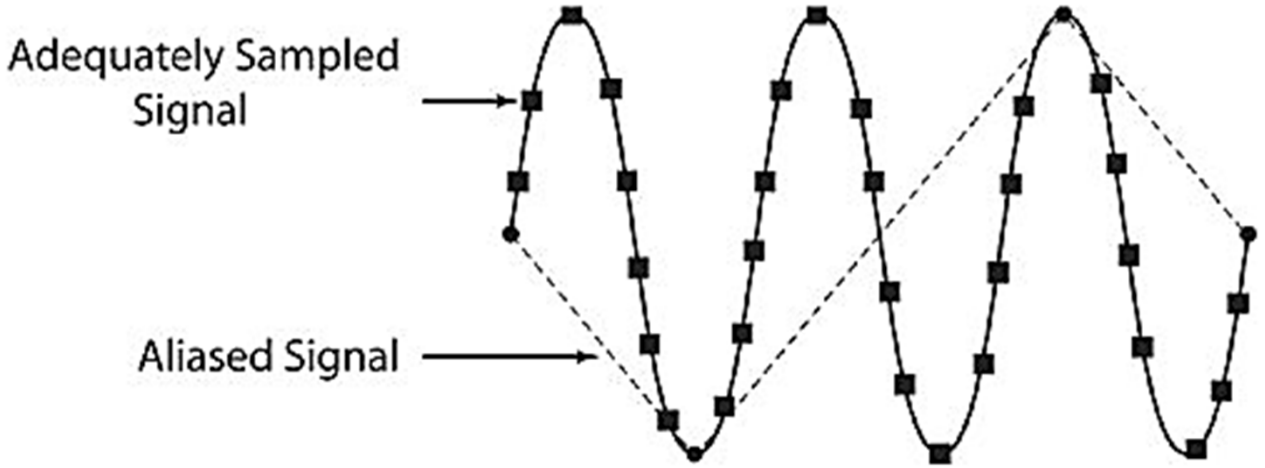
The general guideline for deciding which measurement system to pick is to measure **grounded signal sources with a differential or NRSE system**, and **floating sources with an RSE system**.



The hazard of using an RSE system with a grounded signal source is the introduction of **ground loops**, a possible source of measurement error. Similarly, using a differential or NRSE system to measure a floating source will very likely be plagued by **bias currents**, which cause the input voltage to drift out of the range of the DAQ device (although you can correct this problem by placing bias resistors from the inputs to ground).

Real-world signals are continuous things. To represent these signals in your computer, the DAQ device has to check the level of the signal every so often and assign that level a discrete number that the computer will accept; this is called an analog-to-digital conversion. The computer then sort of "connects the dots" and, hopefully, gives you something that looks similar to the real-world signal (that's why we say it represents the signal).

The sampling rate of a system simply reflects how often an analog-to-digital conversion (ADC) takes place. When the sampling rate isn't high enough, a scary thing happens. Aliasing, while not intuitive, is easy to observe. If we sample 8.5 times slower (the circles), our reconstructed signal looks nothing like the original.



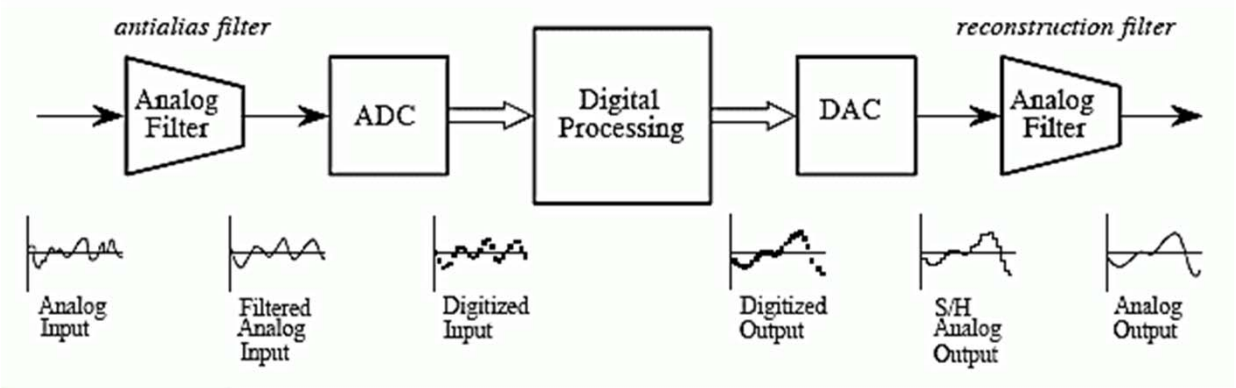
Aliasing has the effect of introducing frequencies into your data that didn't exist in the real-world signal (and removing some that did), thereby severely distorting your signal. Once you have aliased data, you can never go back: There is no way to remove the "aliases." That's why it's so important to sample at a high-enough rate.

How do you determine what your sampling rate should be?

Nyquist's Theorem

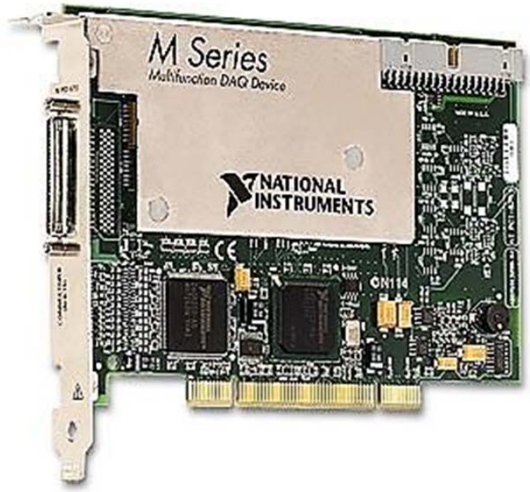
To avoid aliasing, the sampling rate must be greater than twice the maximum frequency component in the signal to be acquired.

The Nyquist Theorem only deals with accurately representing the frequency of the signal. It doesn't say anything about accurately representing the shape of your signal. To adequately preserve the shape of your signal, you should sample at a much higher rate than the Nyquist frequency, generally at least 5 or 10 times the maximum frequency component of your signal.



Introduction to NI LabVIEW

➢ DAQ: NI HW comparison Example



Input analogico		
Numero di canali	8 SE/4DI	16 SE/8 DI
Frequenza di campionamento	48 kS/s	1.25 MS/s
Risoluzione	14 bits	16 bits
Campionamento simultaneo	No	No
Intervallo massimo di tensione	-10..10 V	-10..10 V
Intervallo di accuratezza	138 mV	1920 µV
Intervallo minimo di tensione	-1..1 V	-100..100 mV
Intervallo di accuratezza	37.5 mV	52 µV
Output analogico		
Numero di canali	2	2
Velocità di aggiornamento	150 S/s	2.86 MS/s
Risoluzione	12 bits	16 bits
Intervallo massimo di tensione	0..5 V	-10..10 V
Intervallo di accuratezza	7 mV	2080 µV
Intervallo minimo di tensione	0..5 V	-5..5 V
Intervallo di accuratezza	7 mV	1045 µV
I/O digitale		
Numero di canali	12 DIO	24 DIO
Temporizzazione	Software	Hardware, Software
Livelli di logica	TTL	TTL
Intervallo input massimo	0..5 V	0..5 V
Intervallo output massimo	0..5 V	0..5 V
Contatori/Timer		
Numero di Contatori/Timer	1	2
Risoluzione	32 bits	32 bits
Frequenza di origine massima	5 MHz	80 MHz
Minima ampiezza di impulsi input	100 ns	12.5 ns
Livelli di logica	TTL	TTL
Intervallo massimo	0..5 V	0..5 V